Renewable Energy Opportunities & Challenges

Computational Research Needs for Alternative and Renewable Energy Workshop

September 19, 2007

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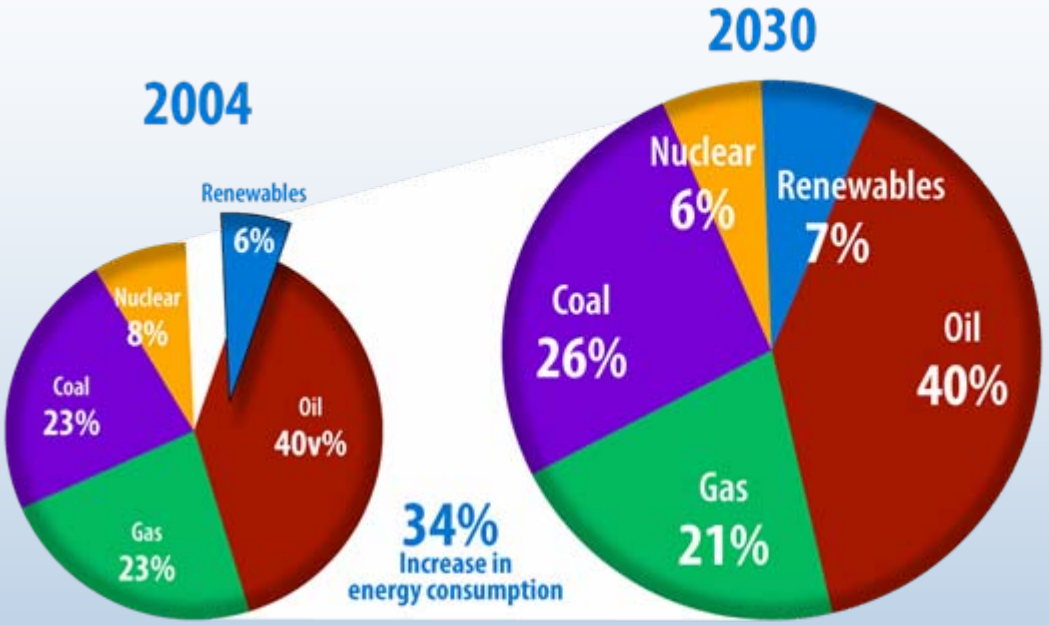
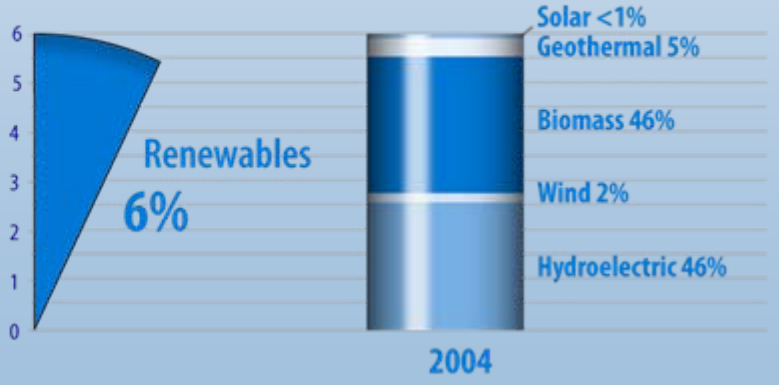
The Key Question

Are energy efficiency and renewable energy technologies poised to have a significant impact?

U.S. Energy Consumption and the Role of Renewable Energy

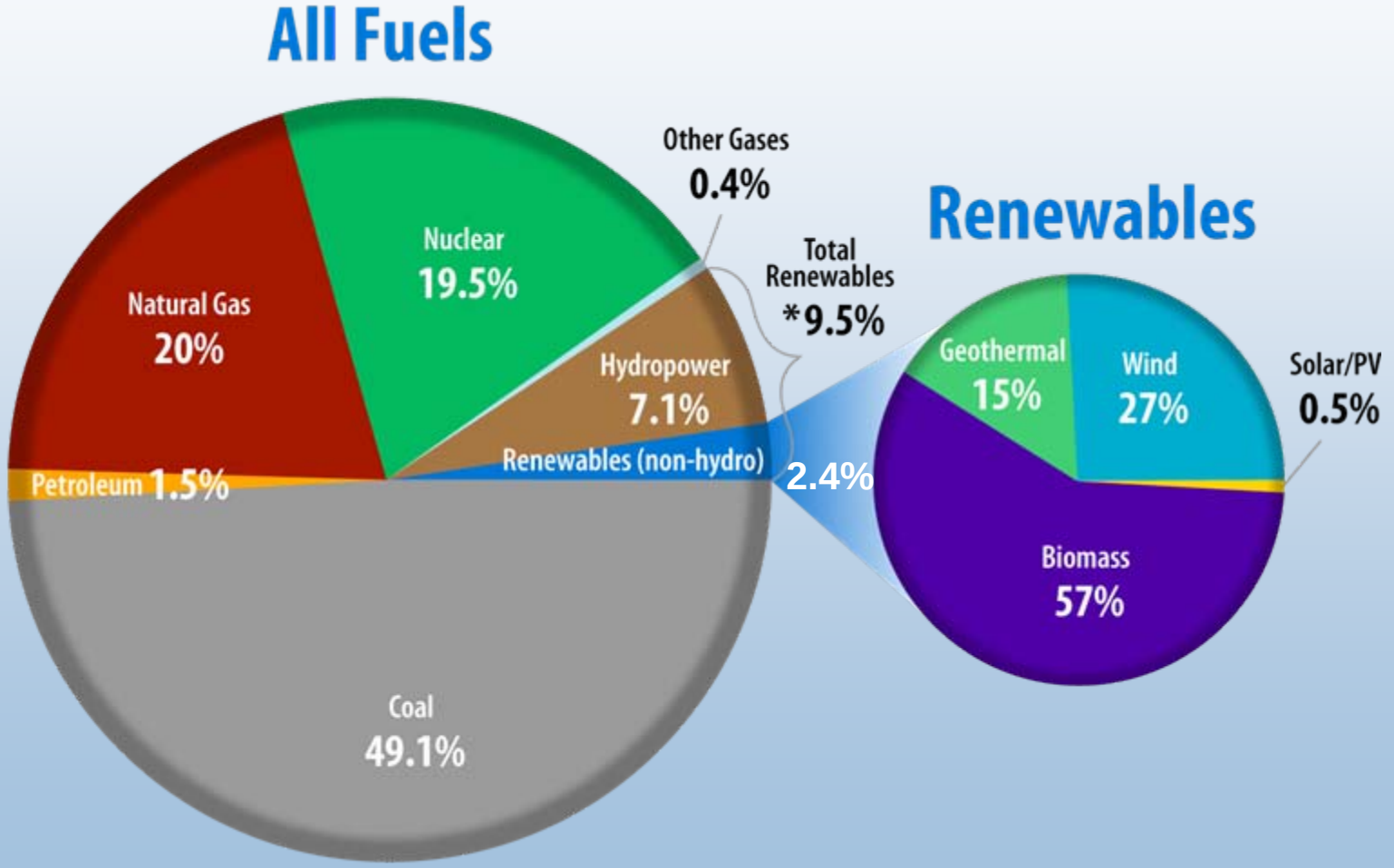




Source: Energy Information Administration, *Annual Energy Outlook 2006,* Table D4

What Are the Major Renewables?

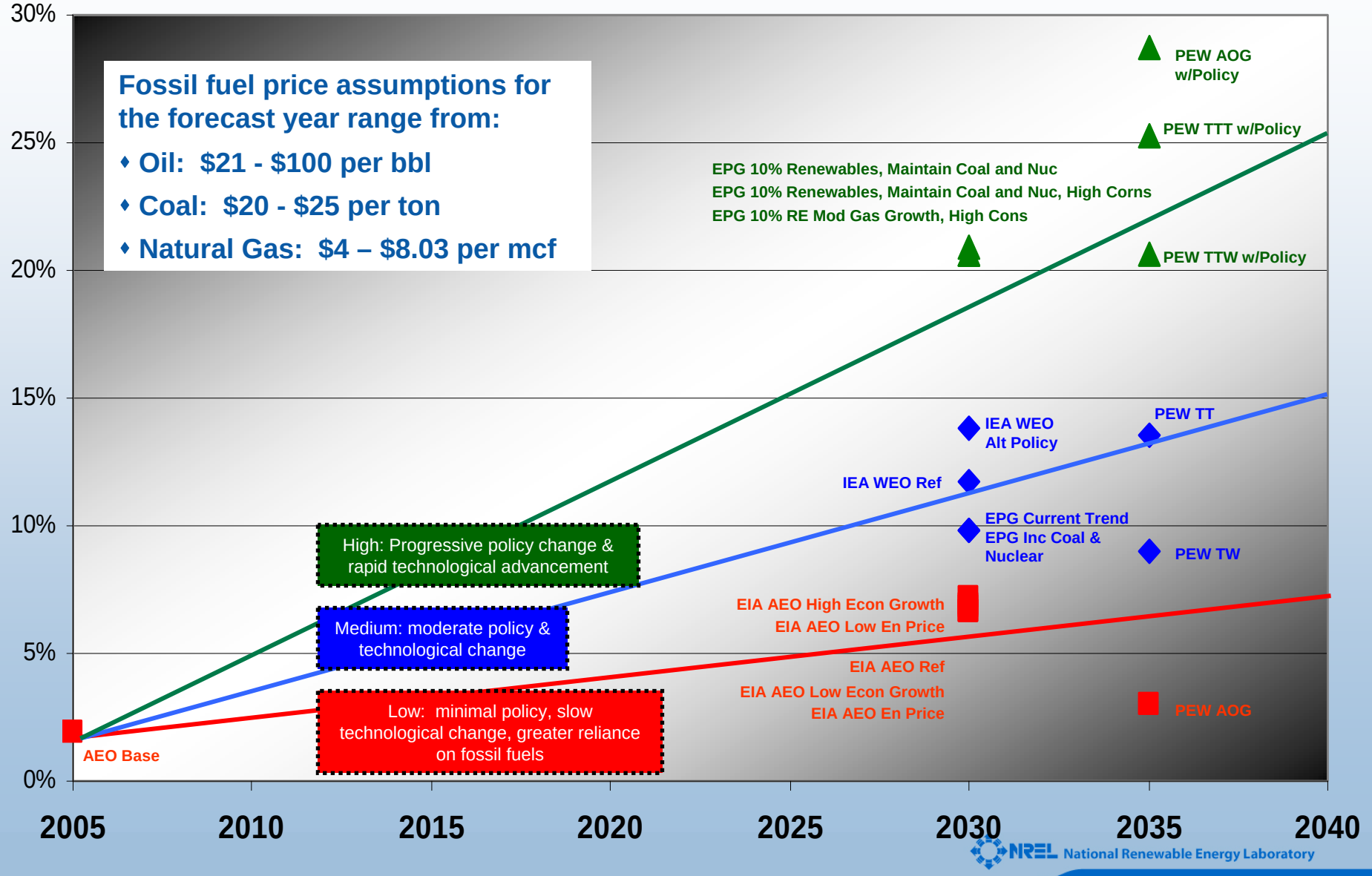
Electricity Net Generation – 2006



* Source: EIA Annual Energy Review 2007

U.S. Renewable Energy Contributions

Percent of Total Electric Generating Capacity



We Are Now Setting Aspirational National Goals – Setting the Bar Higher

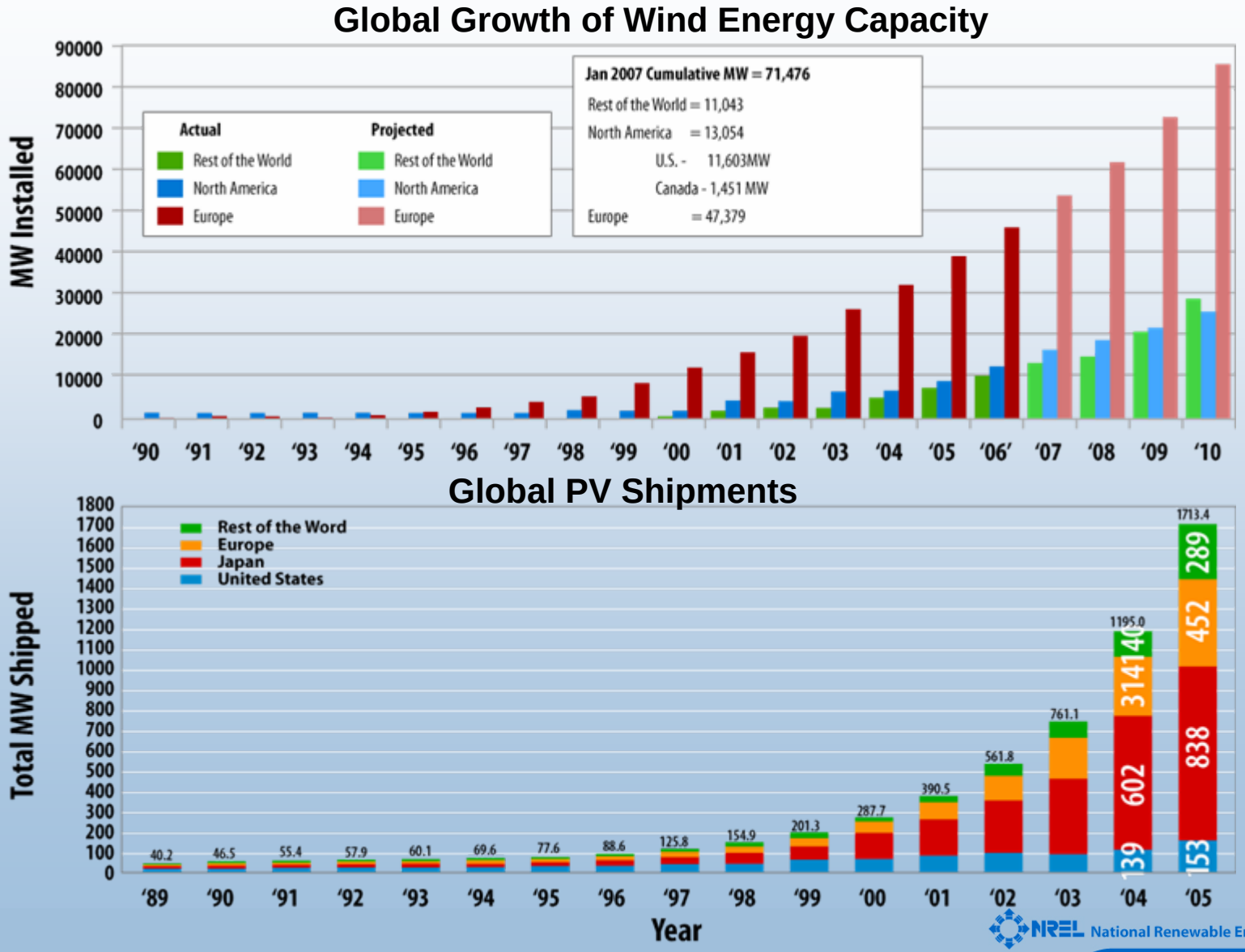
U.S. national goals

- Biofuels: reduce gasoline usage by 20% in ten years
- Wind: 20% of total provided energy by 2030
- Solar: Be market competitive by 2015 for PV and 2020 for CSP

Getting to “Significance” Involves…

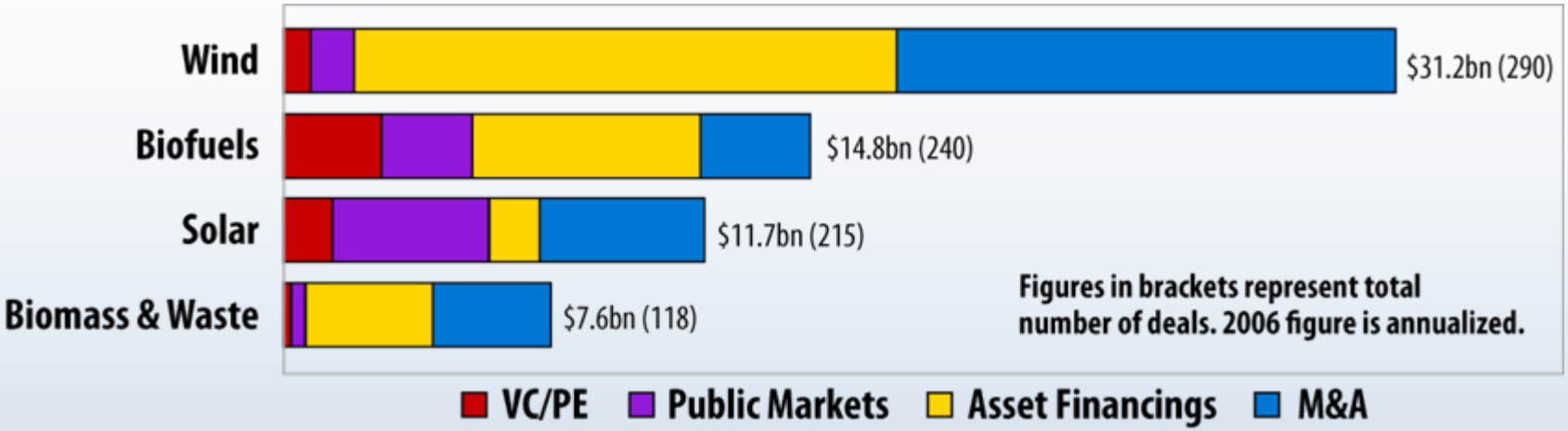
Source: NREL

Global Markets are Growing Rapidly

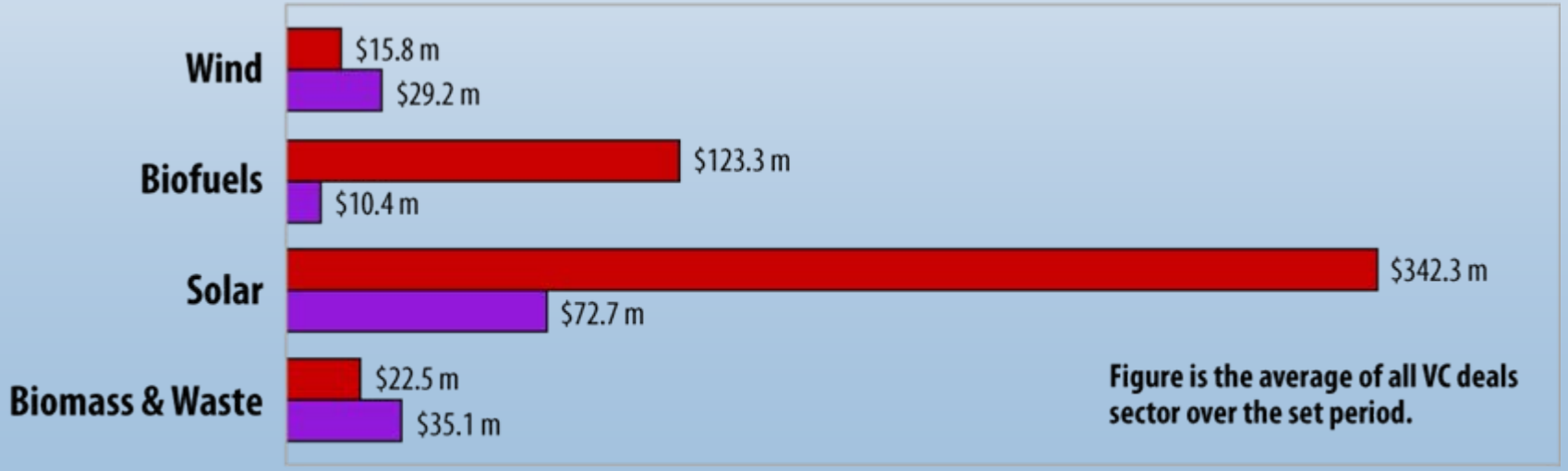


Money Is Flowing Into the Sector

2006 Investment and M&A – By Sector and Asset Class



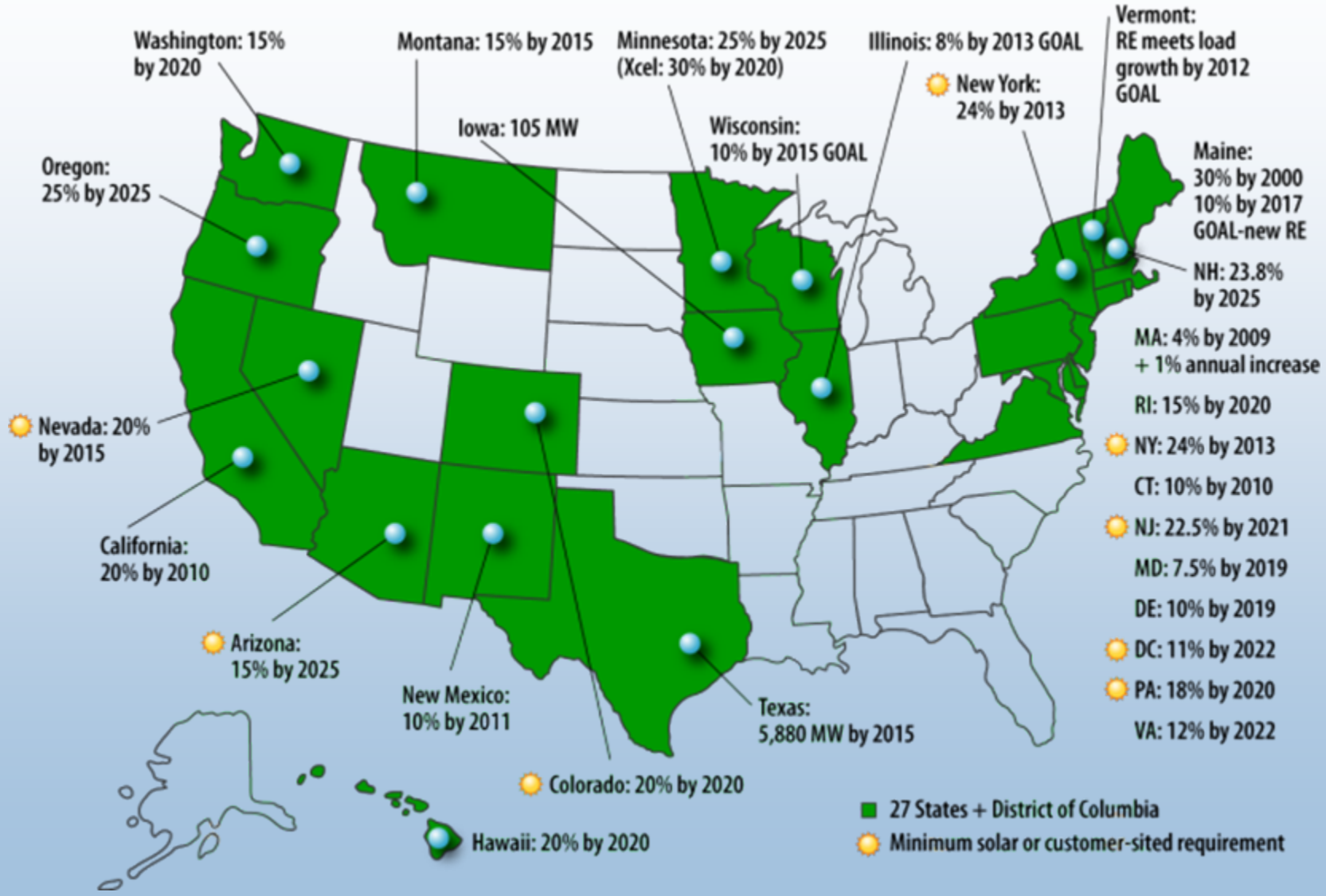
Annual VC Investment Volume – 2001-2004 Compared With 2005-2006



Source: New Energy Finance 2007

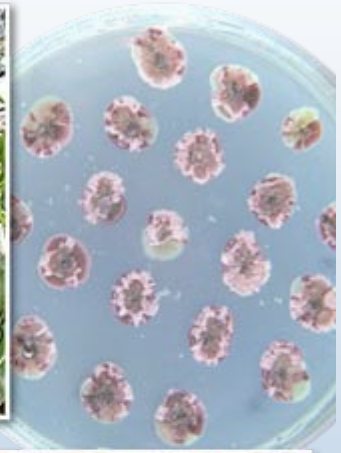
State Policy Framework

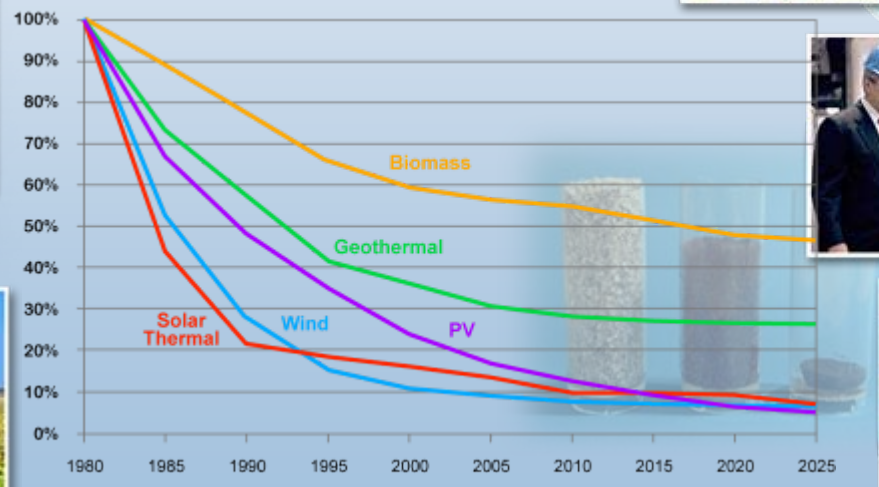
Renewable Electricity Standards



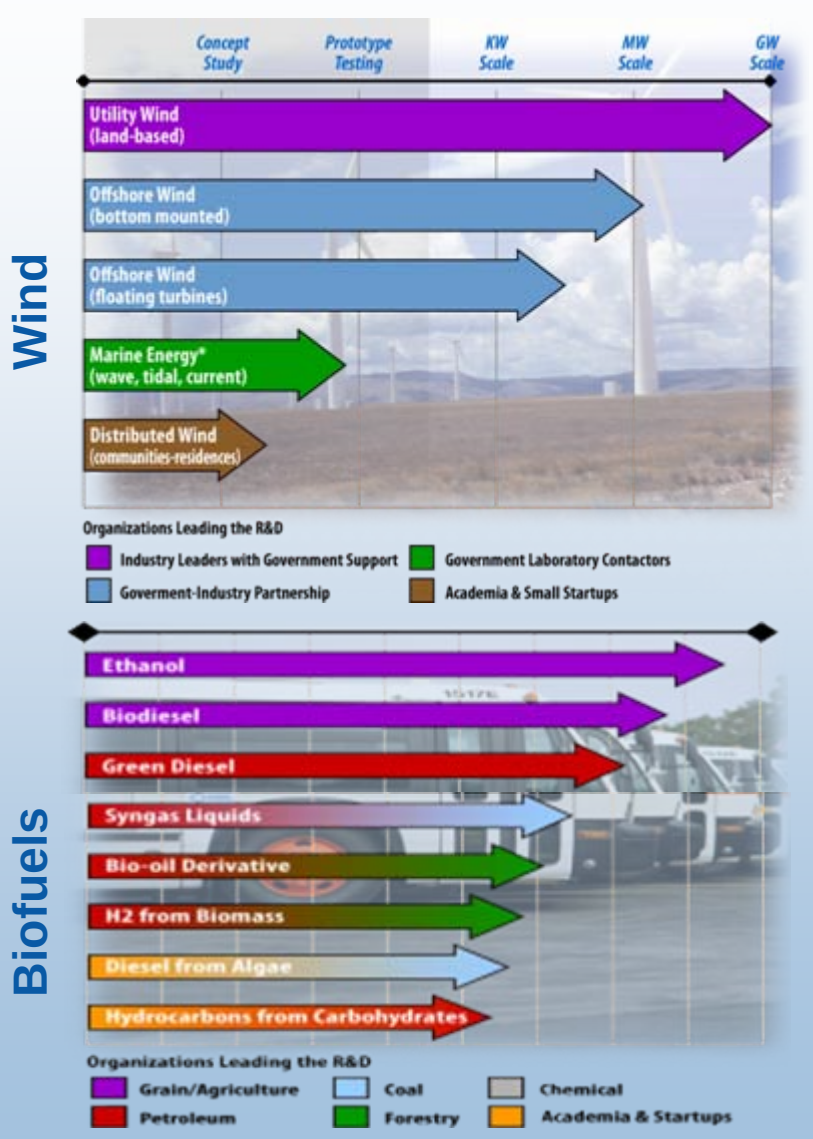
Source: DSIRE database, July 2007

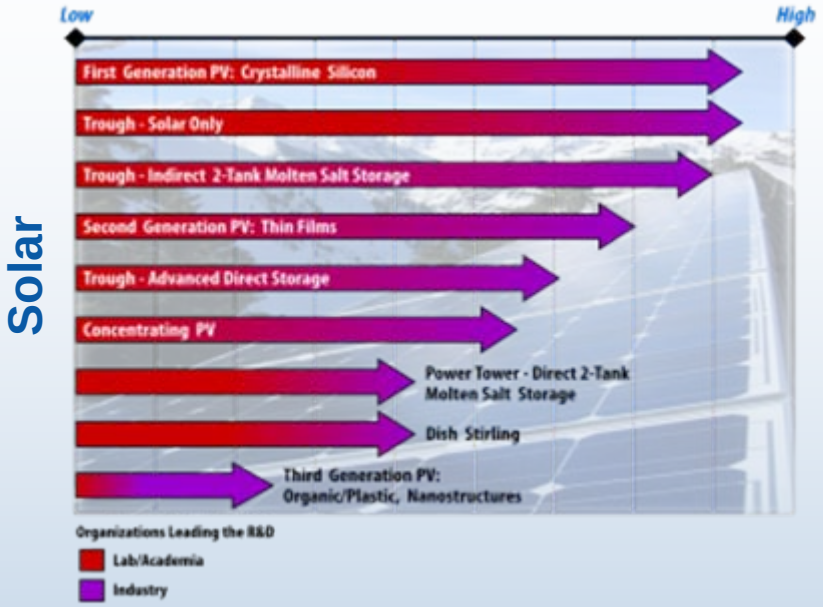
Past Investments Have Yielded Impressive Cost Reductions





Technology Options Are Evolving





Wind

Today's Status in U.S.

- 11,603 MW installed at end of 2006
- Cost 6-9¢/kWh at good wind sites*

DOE Cost Goals

- 3.6¢/kWh, onshore at low wind sites by 2012
- 7¢/kWh, offshore in shallow water by 2014

Long Term Potential

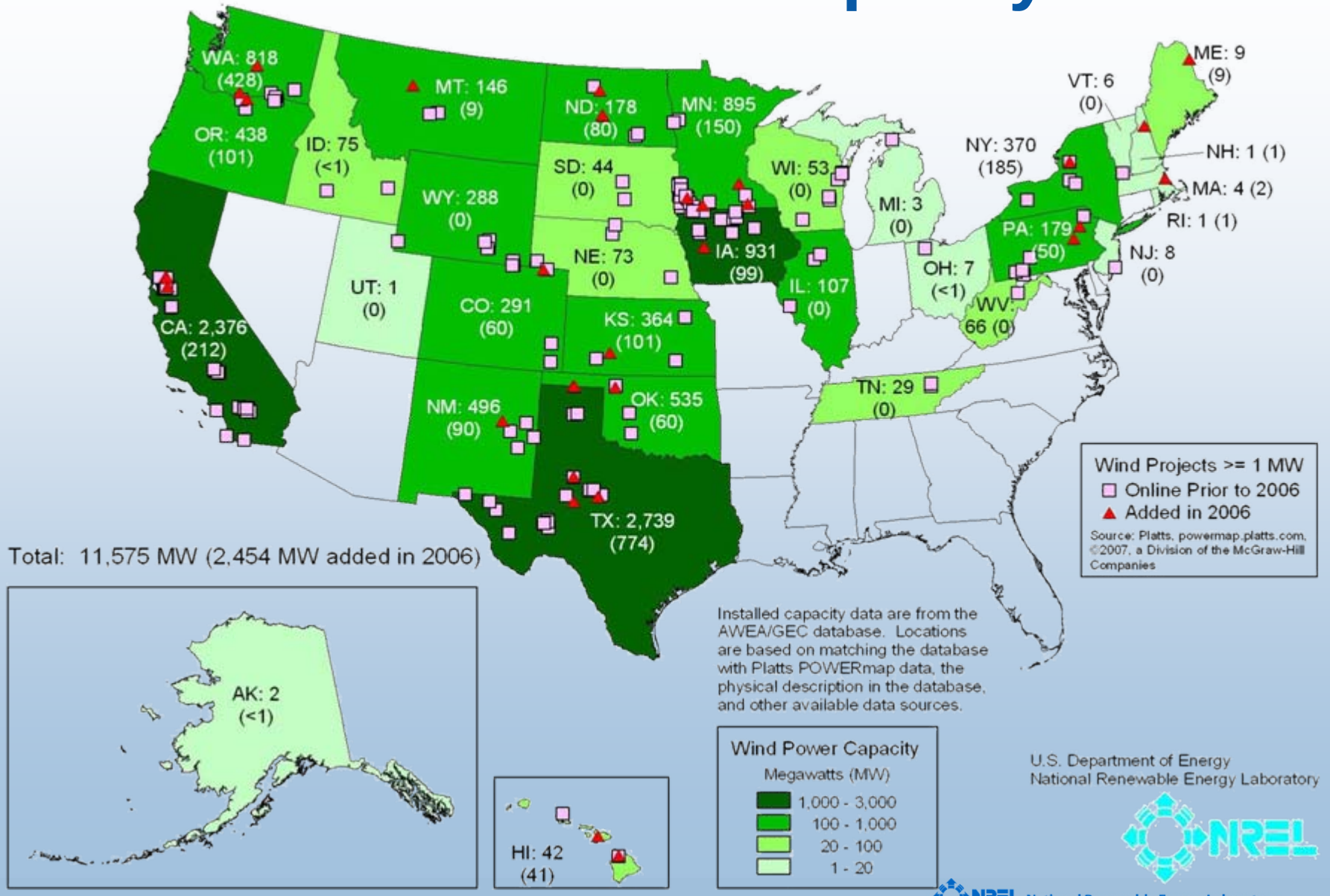
- 20% of the nation's electricity supply

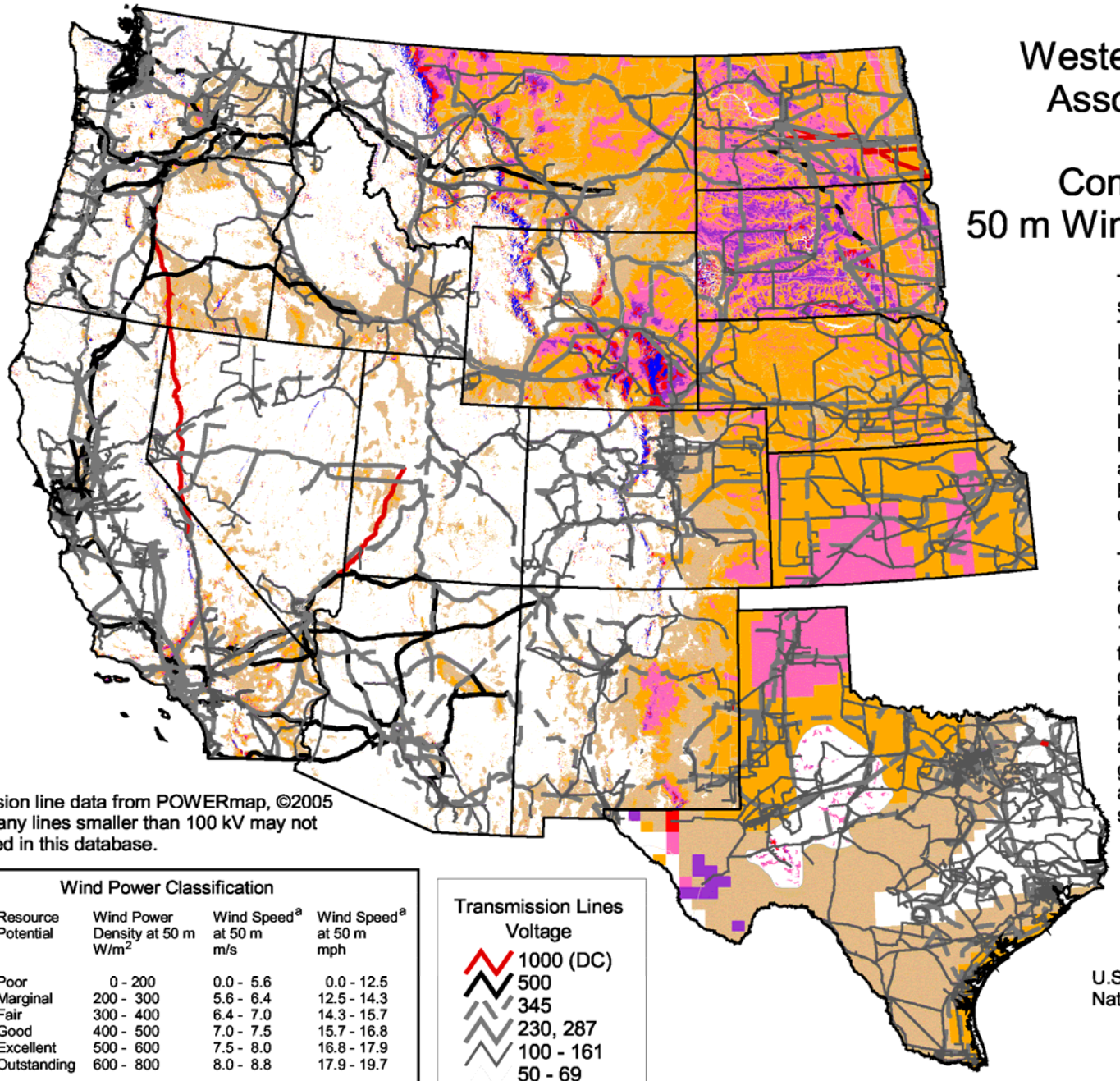
NREL Research Thrusts

- Improved turbine performance and reliability
- Distributed wind technology
- Drivetrain reliability
- Utility grid integration

* With no Production Tax Credit
Updated 1/07, validated 7/07
Source: U.S. Department of Energy, American Wind Energy Association

Installed Wind Capacity





Western Governor's Association Area

Combined Data
50 m Wind Resource Data

The wind resource information shown for Kansas and most of Texas is from the 1987 "Wind Energy Resource Atlas of the United States". Wind resource is shown for every 1/3 degree of longitude by 1/4 degree of latitude. As little as 5% of the area shown in each area may be well-exposed to the power class displayed.

The remaining wind resource assessments were conducted on a state-by-state basis from 1999 to 2004. Over that time, the methodology and resolution of the data varied due to changes in the assessment process. Also, the fine resolution of these assessments may prevent many good resource areas from appearing when viewed at this scale.

Transmission line data from POWERmap, ©2005 Platts. Many lines smaller than 100 kV may not be included in this database.

Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m^2	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
1	Poor	0 - 200	0.0 - 5.6	0.0 - 12.5
2	Marginal	200 - 300	5.6 - 6.4	12.5 - 14.3
3	Fair	300 - 400	6.4 - 7.0	14.3 - 15.7
4	Good	400 - 500	7.0 - 7.5	15.7 - 16.8
5	Excellent	500 - 600	7.5 - 8.0	16.8 - 17.9
6	Outstanding	600 - 800	8.0 - 8.8	17.9 - 19.7

[a] Wind speeds are based on a Weibull k value of 2.0

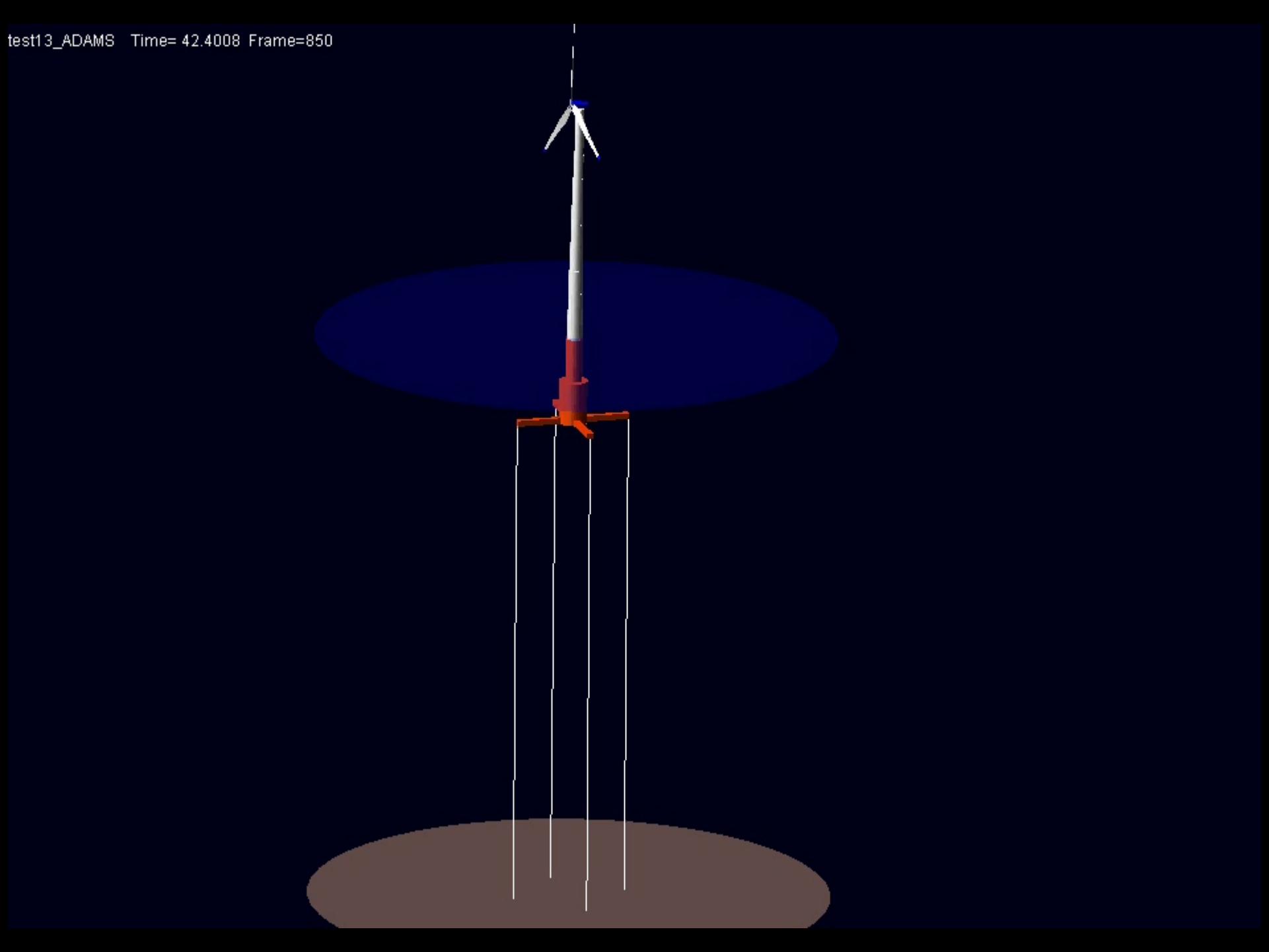
Transmission Lines
Voltage

- 1000 (DC)
- 500
- 345
- 230, 287
- 100 - 161
- 50 - 69

U.S. Department of Energy
National Renewable Energy Laboratory

NREL

11-JUL-2005 5.3.7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Solar

Photovoltaics and Concentrating Solar Power

Status in U.S.

PV
- 565 MW
- Cost 18-23¢/kWh

CSP
- 420 MW
- Cost 12¢/kWh

Potential:

PV
- 11-18¢/kWh by 2010
- 5-10 ¢/kWh by 2015

CSP
8.5¢/kWh by 2010
5-7¢/kWh by 2020

Source: U.S. Department of Energy, IEA, Solar Energy Technologies Program Multi-Year Plan 2007

Updated July 2007

NREL Research Thrusts:

PV
- Partnering with industry
- Higher efficiency devices
- New nanomaterials applications
- Advanced manufacturing techniques

CSP
- Next generation solar collectors
- High performance storage

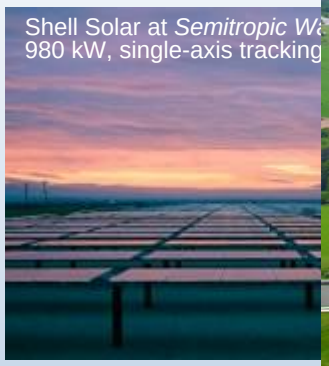
Moving Toward Our Destination


Ridge
Vineyards
PV Rooftop
65 kW, CA

WorldWater & Power, Irrigation System
267 kW, Seley Ranches, CA


RWE Schott Stillwell Avenue Subway Station, PV Canopy Roof, 250,000 kWh/yr, Brooklyn, NY


Powerlight, Bavarian community
6.750 MW, single-axis tracking
Mühlhausen, Germany


Shell Solar at *Semitropic Wa*
980 kW, single-axis tracking


er & Geothermal Energy Co.
stewater Plant, 622 kW,
CA


PowerLight PowerGuard
536 kW, Toyota Motor C


op system,

Biopower

Biopower status

- 2006 Capacity – 10.5 GWe
  - 5 GW Pulp and Paper
  - 2 GW Dedicated Biomass
  - 3 GW MSW and Landfill Gas
  - 0.5 GW Cofiring
- 2004 Generation – 68.5 TWh
- Cost – 0.08 – 0.10 USD/kWh

Potential

- Cost – 0.04-0.06 USD kWh (integrated gasification combined cycle)
- 2030 – 160 TWh (net electricity exported to grid from integrated 60 billion gal/yr biorefinery industry)

Biofuels

Current Biofuels status

- Biodiesel – 1.3 billion gallons/yr capacity[1]
- Corn ethanol
  - 121 commercial plants[2]
  - 6.3 billion gal/yr. capacity[2]
  - Additional 6.2 billion gal/yr planned or under construction
- Cellulosic ethanol (current technology)
  - Projected commercial cost ~$3.50/gge

Key DOE Goals

- 2012 goal: cellulosic ethanol ~$1.62/gge
- 2017 goal : 35 billion gal alternative fuel – President
- 2022 goal: 36 billion gal renewable fuel – Congress/draft
- 2030 goal: 60 billion gal ethanol (30% of 2004 gasoline)

NREL Research Thrusts

- The biorefinery and cellulosic ethanol
- Solutions to under-utilized waste residues
- Energy crops

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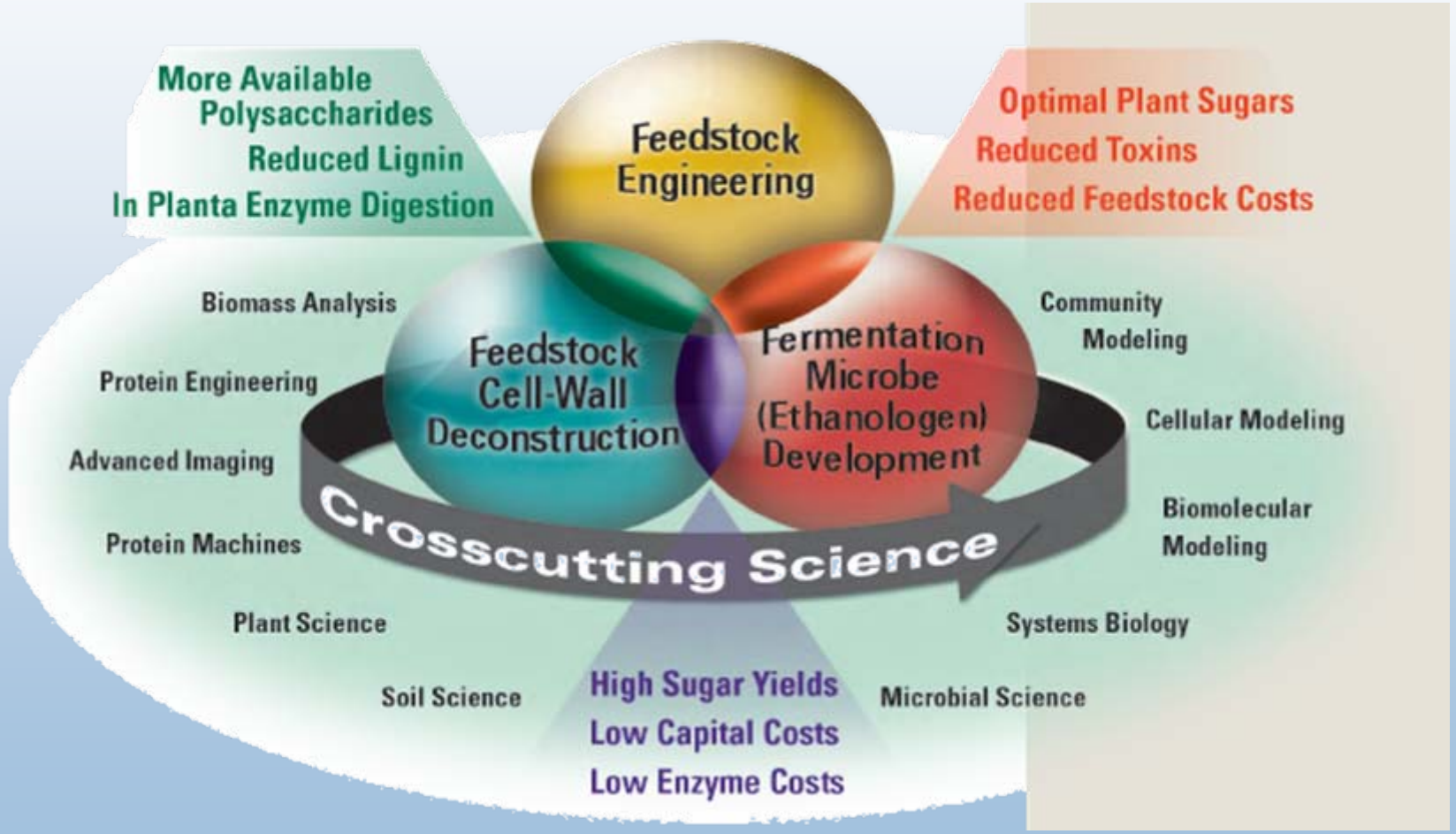
Sources: 1- National Biodiesel Board, 2 - Renewable Fuels Association, all other information based on DOE and USDA sources

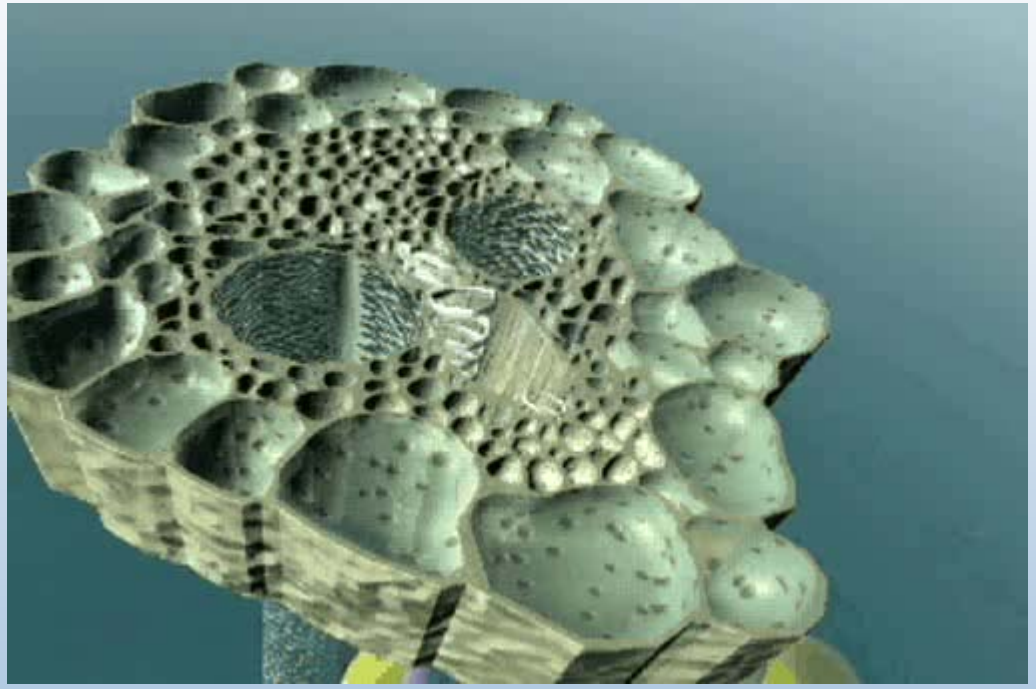
From DOE GTL Bioenergy Roadmap

Systems Biology to Overcoming Barriers to Cellulosic Ethanol



Feedstock Engineering

- Increase crop production (agronomics and plant engineering)
- Increase composition of desirable polysaccharides (cellulose)
- Decrease composition of undesirable polymers (lignins)

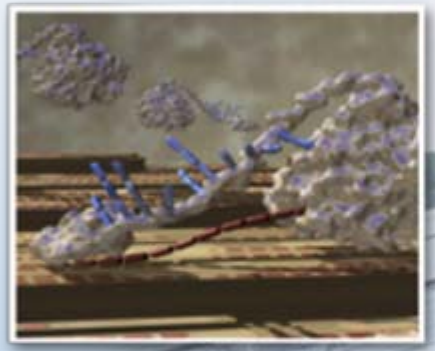


NREL “Corn Stem Tour”

Technology Innovation Challenges Remain

The Next Generation

- Wind Turbines
  - Improve energy capture by 30%
  - Decrease costs by 25%
- Biofuels
  - New feedstocks
  - Integrated biorefineries
- Solar Systems
  - Improved performance through, new materials, lower cost manufacturing processes, concentration
  - Nanostructures
- Zero Energy Buildings
  - Building systems integration
  - Computerized building energy optimization tools

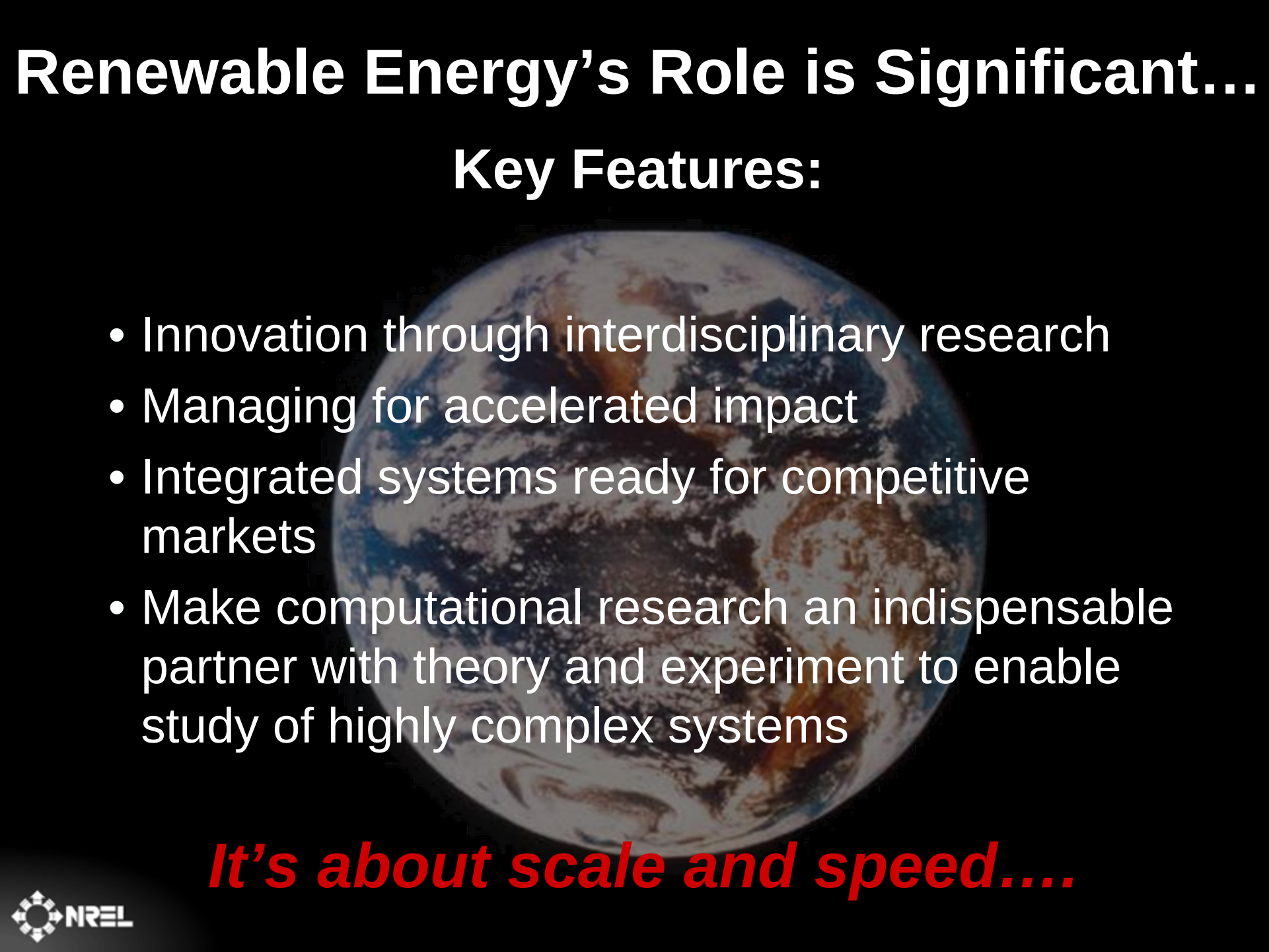


Achieving the Right Balance:
Technology Investment Pathways

Source: NREL 2007

Renewable Energy's Role is Significant…

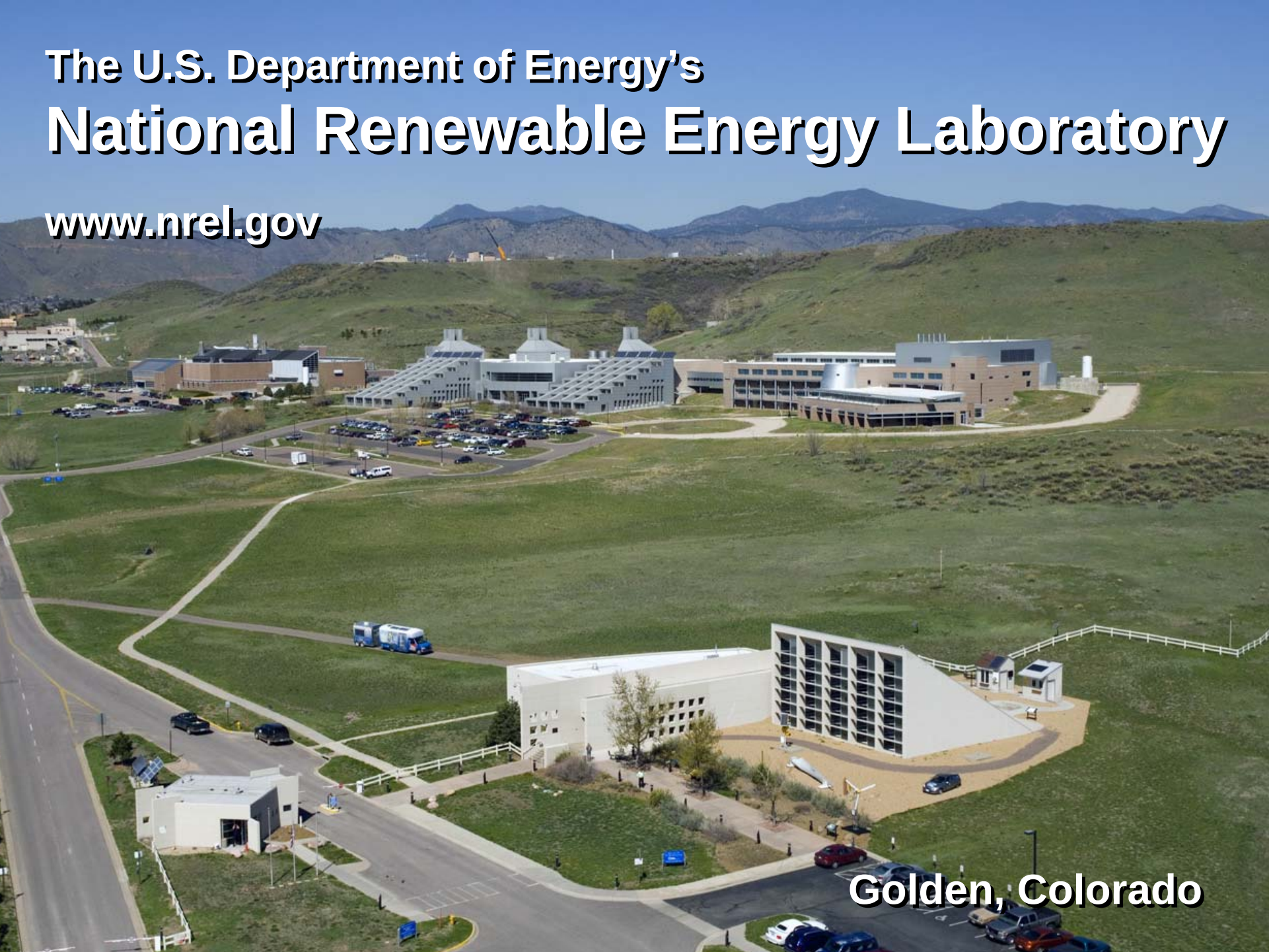
Key Features:



- Innovation through interdisciplinary research
- Managing for accelerated impact
- Integrated systems ready for competitive markets
- Make computational research an indispensable partner with theory and experiment to enable study of highly complex systems

It's about scale and speed….

NREL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